STABILIZATION OF RED SOIL USING BLAST FURNACE SLAG

A Thesis Submitted in Partial Fulfillment
of the Requirements for the Award of the Degree of

Bachelor of Technology
In
Civil Engineering

Submitted by
Bagasingi Rajalaxmi
Roll No. 110ce0142

Under the guidance of
Dr. R. N. Behera

DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY ROURKELA
ROURKELA-769008

CERTIFICATE

This is to certify that the thesis entitled, "**Stabilization of Red Soil Using Blast Furnace slag**" submitted by **Bagasingi Rajalaxmi** in partial fulfilment of the requirement for the award of **Bachelor of Technology** degree in **Civil Engineering** at the National Institute of Technology Rourkela is an authentic work carried out by her under my supervision and guidance. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any degree or diploma.

Place: Rourkela　　　　　　　　　　Dr. R. N. Behera

Date: 11.05.2015　　　　　　　　　　National institute of Technology Rourkela

ACKNOWLEDGEMENT

First and main, I am happy and pleased to God for the blessing that has given upon me in all my endeavours. I am grateful to NIT Rourkela for giving me the exposure and the resources to work on the project.

I am deeply thankful to Dr. R. N. Behera my supervisor, for the motivation, guidance and patience throughout the research work. I appreciate his broad range of knowledge and attention to detail, as well as the constant encouragement he has given me over the years.

I am thankful to Prof. S. K. Sahu, Head of the Department of Civil Engineering for his valuable suggestions during the synopsis meeting and necessary facilities for the research work. And also i am sincerely thankful to Prof. S.K.Das for his kind cooperation.

I would like to be grateful my parents, and family members. Without their love, patience and support, I could not have completed this work. Finally, I wish to thank co-workers of Geotechnical laboratory specially Narayan Mohanty and Dilip Das.

I would like to thank many friends especially, B. Suman, Jayashree Shaoo, and Hrusikesh raymohapatra for giving me support and encouragement during these difficult years.

TABLE OF CONTENTS

LIST OF SYMBOLS

Optimum Moisture Content (%)	**OMC**
Maximum Dry Density (kN/m^3)	**MDD**
Unconfined Compressive Strength (kN/m^3)	**UCS**
Failure Strain (%)	**FS**
Specific Gravity	**G**
Coefficient of permeability (cm/sec)	**k**

ABSTRACT

Now a days, a large acres of land is occupied by industrial waste. It not only creates land problem but also creates environmental problems. In order to utilise the industrial waste, an attempt is made to stabilise the red soil by adding blast furnace slag.

This project work aims to evaluate the effect of addition of 0%, 5%, 10%, 15%, 20% blast furnace slag in order to stabilize the red soil and to verify its suitability to be used as a construction material for road, embankment and structural fills. The blast furnace slag is collected from Rourkela Steel Plant and the red soil is collected from the campus of National Institute of Technology Rourkela for evaluating its suitability as a construction material for various geotechnical works. Its consistency properties, compaction properties, and strength parameter are tested. In this project the effects of addition of blast furnace slag is investigated and is compared with that of the virgin red soil. The overall testing program was conducted in two phases. In the first phase, the physical, and chemical engineering properties of the red soil samples were studied by conducting Hydrometer analysis, Light compaction test and UCS test. In the second phase of the test program, red soil was mixed with 0%, 5%, 10%, 15%, and 20% of blast furnace slag as percentage of dry weight of red soil. The particular UCS samples were cured for 3, 7, 15 days with varying ambient temperature. Based on the analyses of experimental results the Plasticity Index is decreasing up to a value of 27.6% with addition of 20% of blast furnace slag with red soil. The UCS value is maximum with addition of 10% of blast furnace slag afterwards the UCS value decreases with further addition in blast furnace slag.

Keywords; red soil, blast furnace slag, stabilization.

CHAPTER 1

INTRODUCTION

Stabilization of soil in a broader sense is the modification of the properties of a soil is improving its engineering performance. Soil stabilization is broadly used in connection with road, pavement and foundation construction. It improves the engineering properties of the soil in terms of volume stability, strength, and durability. Soil stabilization occurs over a longer time period of curing. The effects of blast furnace slag stabilization are usually measured after 0days, 3days, 7days, 15days, 28days or longer. A soil that is treated with blast furnace slag is modified and its properties are changed which may lead to stabilisation. When sufficient amount of blast furnace slag is added to the soil, stabilization occurs. Stabilization is different than modification as strength increases. Over a long time period, the strength increases up to the addition of 10% of blast furnace slag. Red soil is generally, is derived from weathering of ancient metamorphic rocks of the ancient Deccan plateau. It is red colour due to the abundance of iron in it. When iron content is suitably lower, the colour will be yellow or brown colour. Red soil is usually that group of soil that develops in warm temperature and is generally abundant in moist climate where deciduous or mixed forests are present. They generally have a thin organic and inorganic mineral layer overlaying a yellowish brown layer resting on the alluvial deposits. Red soil is available in many states of India. Red soil is generally found in Odisha, Tamil Nadu, Karnataka, Maharashtra, Chhattisgarh, Birnbaum (West Bengal), Mirzapur, Jhansi, Haripur (Uttar Pradesh), Udaipur, Durgapur, Batswana and Bhilwara districts (Rajasthan), Chotanagpur plateau of Jharkhand, AndhraPradesh.

Blast furnace slag is use to make iron operate on temperatures capable of 2000°C and are feed with a carefully to inhibited mixture of limestone, iron ore, and coke. The iron ore transfer to iron which sink to the base of the furnace. Blast furnace slag is a by-product material generate by thermal power plants from combustion of iron, iron ore, iron scrap, and fluxes (limestone or dolomite) are charged into a blast furnace along with coke for fuel. The coke is combusted to produce carbon monoxide, whichreduces the iron ore to molten iron product. This molten iron product can be iron products, but it is most often used as a feedstock for steel production. Blast furnace slag is a non-metallic co-product produced in the process. It consists primarily of silicates, alumina silicates, and calcium alumina silicates. The molten slag, which absorbs much of the sulphur from the charge, comprises about 20 percent by mass of iron production. The blast furnace slag is considered as a waste disposal which can be used in the construction material like road, pavement, railway ballast, landfills etc.

LITERATURE REVIEW

Many research works have been done on the properties of red soil and blast furnace slag by the different researchers for study in their suitability as a construction material in various field of civil Engineering. They are;

Akinmusuru (1991) studied the cause of mixing of GGBS on the consistency, compaction characteristics and strength of lateritic soil. He observed a decrease in both the liquid and plastic limits. The compaction, cohesion and CBR improved with increasing GGBS up to 10% then if add 15% of GGBS decrease the strength. The angle of internal friction decrease with increase GGBS percentage.

Wild et al. (1995) explained the results of laboratory testing on lime-stabilize kaolinite containing different quantities of added sulphate to which different quantities of GGBS have been added. The experiment determine the strength increase of compacted cylinders, moist cured in a humid temperature at 30 and the linear growth of these moist cured cylinders on soaking in water. The results clarify that slight additions of GGBS to sulphate containing clays which are stabilized with decrease their expansion.

Hogan and Meusel (1981) studied the assessment of a ground granulated blast furnace slag is a limited replacement for Portland cement in mortars and concrete. The ground slag was evaluated for strength-constructing properties as well as durability concert by replacing 40 to 65% Portland cement with it. This study presented that the ground slag when used to interchange 40 to 65% Portland cement expressively improved strengths, resistance, sulphate, and alkali aggregate.

Higgins (2005) studied the soil stabilization in ground granulated blast furnace slag. In this paper lime and ground granulated blast furnace slag is added in the soil to stabilize the soil.

Lime and GGBS is the ideal option where there are sulphate and sulphides are present in the soil.

Ghosh and Subbaro (2007) found that the strength of lime treated soil is increased and is dependent on curing period and compactive energy.

Manjunath (2011) studied the mixing of blast furnace slag (an industrial waste) with hydrated lime is used to stabilize atypical black cotton soil. The addition of blast furnace slag and lime to increase the geotechnical property of soil.

Sayida and Saijamol (2011) studied the improving engineering property of the soil. They added chemical then react with cementing compound. The present analysis is kaolinite clay is mixed with different proportion of fly ash and sea sand .Then the addition of sand raise the CBR value.

Vaclavik et al. (2012) this paper deals with physical and mechanical property of experimental concrete mixtures based on finely granulated blast furnace slag be observed the consistency of concrete mixture and determination of cube strength of the concrete.

Yadu and Tripathi (2013) used the blast furnace slag (BFS) to stabilize a soft soil. Based on the strength performing the optimum BFS was determined 9%. The increase of the strength has been observed un-soaked and soaked California bearing ratio.

Terhreemna and Kalita (2013) investigated the effect of class F fly ash and lime on the strength property of the red soil by experimentation.

Pathak et al. (2014) studied the soil stabilization using ground granulated blast furnace slag (ggbs).The main object of this research is the effect of GGBS engineering property of the soil like Liquid limit, Plastic limit, Plasticity index, Moisture content , Dry density, Unconfined compressive strength, triaxial test, California baring ratio determine the engineering property of the soil and the GGBS is added upto 25% in the soil.

CHAPTER 2

SCOPE AND OBJECTIVE OF THIS PROJECT

The aim of this project is follows;

- Determination of the engineering properties of red soil sample as well as blast furnace slag sample.
- Determination of chemical composition of red soil as well as blast furnace slag sample.
- Determination of optimum blast furnace slag content on strength characteristics of red soil and blast furnace slag mixture.
- Effect of optimum blast furnace slag content on index properties, volume stability, durability, atterberg limit (i.e liquid limit, plastic limit, plasticity index) of red soil and blast furnace slag mixture.
- Effect of curing period of the strength of the soil.
- Effect of curing period of red soil addition of the blast furnace slag of strength.

CHAPTER 3

MATERIAL USED

3.1 MATERIALS TO BE USED

- Red soil
- Blast furnace slag

3.2 RED SOIL

Red soil is derived from weathering of ancient metamorphic rock of the Deccan plateau. Red soil is any of a group of soil that grow in a humid temperature, moist climate under deciduous and mix forests and that have raw mineral. Thin organic layers overlying a yellowish brown leached deposit resting on an alluvial. Their colour is mostly ferric oxides occurring a slight coatings on the soil particle through the iron oxide arise as hematite as hydrous ferric oxide, the colour is red and when it happen in the hydrate system as limonite the soil become to be yellow colour. Generally the surface soils are red while the horizon under gets yellowish colour.

Figure 1: Red soil

3.3 BLAST FURNACE SLAG

Slag is a derivative of the iron-making method. When it is quench with water and rapidly chilled, it forms a smooth granulated material of sand-like consistency. While its high calcium silicate content, it become tremendous cementations properties. When finely crush and combined with a suitable activator, slag sets in a manner related to Portland cement. Additional information on blast furnace slag use in the United States can be obtained from; National Slag Association 808 North Fairfax Street Arlington, Virginia 22314Blast

Blast furnace slag is used to make iron operate at temperature up to 2000°C and are feed with a cautiously to controlled mixture of iron coke ,ore, and limestone. The iron ore change to iron which drop to bottom most of the blast furnace slag. Blast furnace slag is a by-product material generated by thermal power plants from burning of iron ore, iron scrap, iron and fluxes (limestone or dolomite) charged into a blast furnace along with coke for fuel. The coke is combusted to produce carbon monoxide, which reduce the iron ore to molten iron product. This molten iron product can be iron product, but it is most often used as a feedstock for steel production. Blast furnace slag is a non-metallic co-product produced in the process. It consists primarily of alumina silicates, and calcium alumina silicates, silicates. The molten slag, which absorb much of the sulphur from the charge, comprise about 20 percent by mass of iron production. The blast furnace slag is considered as a waste disposal which can be used in the construction material like pavement, road, landfills, railway ballast, etc. Different types of slag produce depending on the method used to cool the molten slag. The blast furnace slag (BFS) is immerse the sulphur as of the charge comprises about 20% of iron product. There are different forms of slag produced depending on the methods used to cool the molten slag.

The product involved air cooled blast furnace slag are;

- Air cooled blast furnace slag(ACBFS)
- Expanded or foamed blast furnace slag(EBFS)

- Pelletized blast furnace slag(PBFS)
- Granulated blast furnace slag(GBFS)

Figure 2: Blast furnace slag

METHODOLOGY

The following set of experiments are intended to be carried out;

- atterberg limit
    - Plastic limit
    - Liquid limit
    - Plasticity index
- Specific gravity test
- Free swelling index
- Sieve analysis
- Compaction characteristics
    - Light compaction test
    - Maximum dry density
    - Optimum moisture content
- Strength characteristics.

- Unconfined compression test

- Chemical composition of red soil, blast furnace slag as well as mixture of red soil.

CHAPTER 4

EXPERIMENTAL PROCEDURE

4.1 ATTERBERG LIMITS

The **Atterberg limits** are basic amount of the acute water content of the fine-grained soil, such as plastic limit and liquid limit. As a dry, clayey soil takes on increase amounts of water, it undertake affect and distinct variation in behaviour and consistency. Depending on the water content of the soil, it may come into in four states:

- solid
- semi-solid
- plastic
- liquid

In each state, the constancy and behaviour of the soil is changed accordingly its engineering properties. Thus the limit between each state be capable of defined based on a difference in the soil behaviour. The Atterberg limits can be used to make a distinction between silt and clay, and it can distinguish between different types of silts and clays.The objective of the Atterberg limits test is to get critical index information about the soil used to estimation strength and the settlement characteristics. It is the primary form of classification for cohesive soils.

4.2 PLASTIC LIMIT (as per IS: 2720 (Part 5) 1985)

The plastic limit is determine plastic limit of the red soil. The plastic limit is defined as the moisture content where the thread breaks apart at a diameter of 3 mm.PL is Compute the average of the water contents obtained from the three plastic limit tests. The plastic limit (PL) is the average of the three water contents.

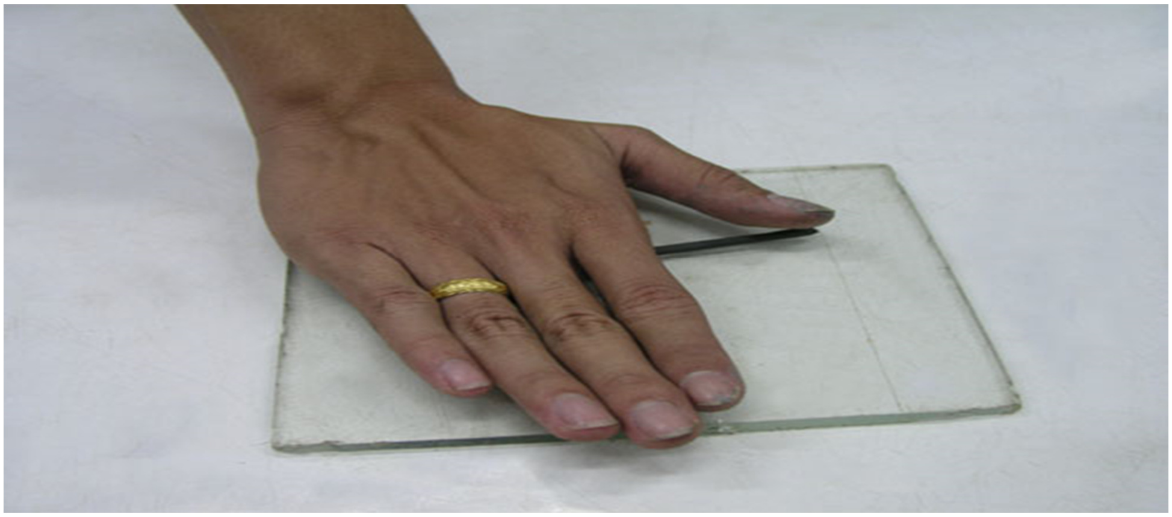

Figure 3:plastic limit test

4.3 LIQUID LIMIT [IS: 2720 (Part 5) 1985]

The liquid limit is most commonly perform of the Atterberg Limits along with the plastic limit. These 2 tests are used internationally to classify soil. The liquid limit is define the moisture content at which soil begin to behave as a liquid material and soil begins to flow. The liquid limit is determine in the lab as the moisture content at which the two sides of a groove shaped in soil come simultaneously and touch a distance of 2 inch after 25 blows. it is very tricky to get this to occur value exactly, we will run the test repeatedly until the groove closes 1/2 inch with over 25 blows. We can plot these results as no of blow versus moisture content and interpolate the moisture content at 25 blows from the graph.

FREE SWELLING INDEX [IS: **2720 (Part XL) – 1977]**

Free swell or depending the free swell, also term as free swell index, is the increase in volume of soil with in 24 hours without any external limitation when subjected to submergence with water and kerosene.

4.4 SPECIFIC GRAVITY [IS: 2720 (Part-III/SEC-I)]

Specific gravity is defined as the relative amount of the weight in air of a given volume of a material at a specified high temperature to the weight in air of an the same volume of distilled water at a specified temperature. The reason of the test is to characterize the specific gravity of red soil passing the 4.75 mm sieve by density bottle method. 50g of sample of red soil and blast furnace slag is taken in each 3 bottles and added water then weight of the water + bottle is taken. Then all the 3 bottles are subjected to sand bath, heating is done up to air bubbles are seen in the bottle. This is done to remove the entrapped air in the mixture; the bottle is kept for around 15min so that the temperature comes to 27oC.

ENGINEERING PROPERTY OF RED SOIL

Soil property	**Result**
Liquid limit	41%
Plastic limit	20.15%
Plasticity index	19.85%
Free swelling index	0
Specific gravity	2.64
Dry density g/cc	1.775
Moisture content	15%

Table 1:engineering property of red soil

VARIATION OF PLASTICITY INDEX AFTER ADDING 5%,10%, 15%, 20% BLAST FURNACE SLAG

Plastic limit of red soil	20.15 %	Liquid limit for red soil	41 %	Plasticity index for red soil	19.85%
Plastic limit of red soil +5% bfs	19.77 %	Liquid limit for red soil+ 5% bfs	36.10%	Plasticity index for red soil +5% bfs	16.33%

Plastic limit of red soil +10% bfs	16.41 %	Liquid limit for red soil+ 10% bfs	35.30%	Plasticity index for red soil +10% bfs	18.89%
Plastic limit of red soil +15% bfs	16.05 %	Liquid limit for red soil+ 15% bfs	32.02%	Plasticity index for red soil + 15% bfs	15.96%
Plastic limit of red soil +5% bfs	15.67 %	Liquid limit for red soil+ 20% bfs	30.3%	Plasticity index for red soil +20 % bfs	14.37%

Table 2:plasticity index of red soil after addition of blast furnace slag

4.5 SIEVE ANALYSIS:

This test is perform to determine the proportion of different grain sizes contain with in a red soil. Sieve analysis is perform to determine the distribution of the coarser, larger-sized particles. Grain size analysis provides the grain size distribution, and it is required in classifying the soil.

Figure 4: Sieve Set

4.6 PROCTOR COMPACTION TEST

Proctor compaction test is a laboratory method of test is to define the optimal moisture content at which a given soil type will specifically. To determine the optimum water content at which soil be able to get to its maximum dry density. The soil is then located and compacted in the Proctor compaction mould in three different layers where each layer receives 25 blows of the standard hammer. Before insertion each layer, the exterior of the layers is scratched in order to verify a uniform distribution of the compaction. At the end of the test, after eliminate and drying of the sample, the dry density and water content of the sample is determine for each Proctor compaction test. Based on the 3 of results, a graph is plotted between the dry density and moisture content. From this graph, the optimum water content to achieve the maximum dry density can be found. The moisture content, and dry density relations be initiate by compaction tests as per IS: 2720 (Part VII) 1980.Red soil is stabilized with variable percentage of BFS (0%, 5%, 10%, 15% and 20%) of its dry weight. For this test, red soil is thoroughly mixed with suitable amount of water and the wet sample is compacted in proctor mould in three layers. Using standard proctor rammer of 2.6 kg and modified proctor rammer of 4.5 kg. As per IS: 2720 (Part 2) 1973 the moisture content of the compacted mixture is determined. From the dry density and moisture content correlation, optimum moisture content (OMC), and maximum dry density (MDD) were determined. Similar compaction tests were shown with varying. Percentage of BFS (0%, 5%, 10%, 15% and 20%) and the corresponding optimum moisture content (OMC) and maximum dry density (MDD) were determined. This was done to study the effect of BFS content and compactive energy of OMC and MDD.

Figure 5: proctor compaction test

Table 4: MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE

Blast furnace slag(%)	Moisture content(%)	Dry density g/cc
0	15	1.775
5	16	1.779
10	17	1.8
15	18	1.802
20	19	1.812

4.7 UNCONFINED COMPRESSIVE STRENGTH

Samples of height 10 cm and diameter 5cm with a volume of 196.34 cu.cm are made.

Unconfined compression tests of red soil with blast furnace slag percentages of 0, 5, 10, 15, and 20% are conducted. Curing period of 0, 3, 7, and 15 days are adopted. A total of 60 UCS tests have been conducted with blast furnace slag.

UCS SAMPLES ARE CURED IN DIFFERENT PERCENTAGE OF BFS

Figure 6: ucs samples

4.8 XRD ANALYSIS OF RED SOIL

The mineralogical study of the material has been prepared by XRD analysis by X-ray diffract meter which is built on the principle that beams of X-rays diffracted after crystals are characteristics to each clay mineral group. The XRD analysis results for both the soils and blast furnace slag.

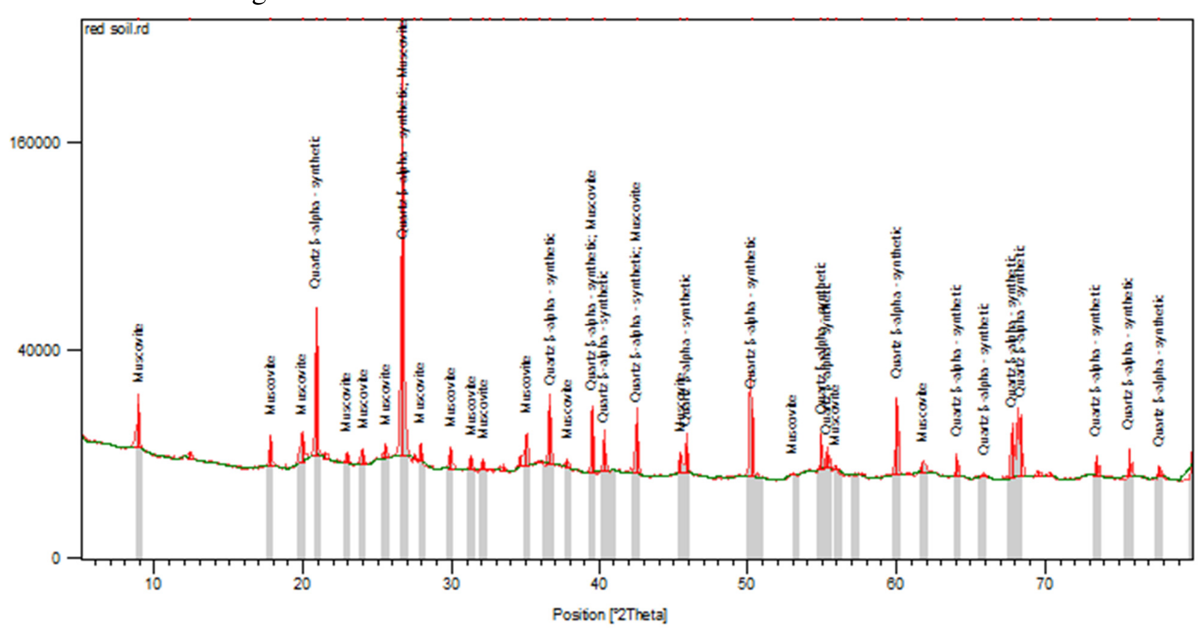

Figure 7: XRD analysis of red soil

Compound name	Chemical formula
Quartz alpha synthetic	Si O_2
Muscovite	H2 K Al3 (Si O4)3

4.9 XRD ANALYSIS OF BLAST FURNACE SLAG

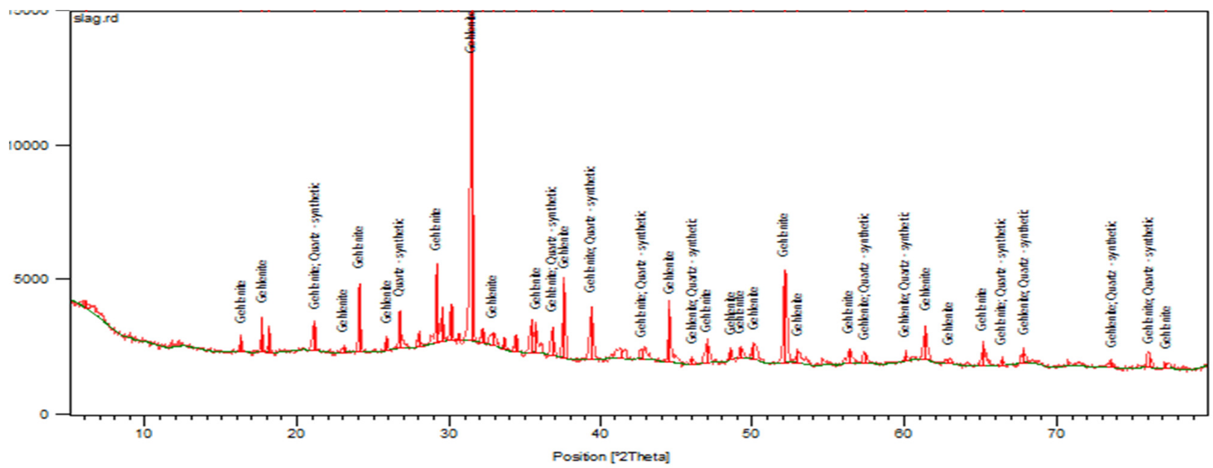

Figure 8:XRD analysis of blast furnace slag

Compound name	Chemical formula
Gehlenite	(Ca1.96 Na.05) (Mg.24 Al.64 Fe.12) (Si1.39 Al.61 O7)
Quartz - synthetic	Si O2

CHAPTER 5
RESULTS AND DISCUSSION

ENGINEERING PROPERTY OF THE RED SOIL

5.1 LIQUID LIMIT

The liquid limit test is determined for plasticity index.in the liquid limit test added different % of blast furnace slag then the liquid limit is decreses.so that the plasticity index is decreases.

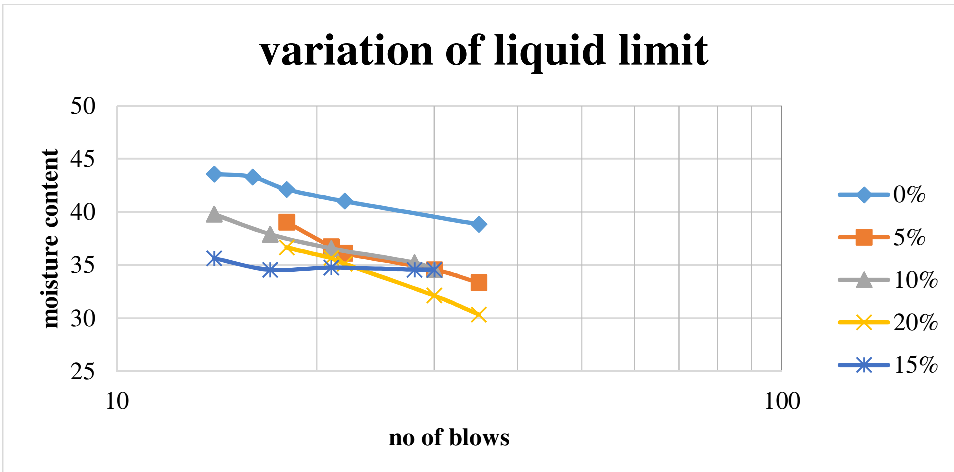

Figure 9: variation of liquid limit

5.2 LIGHT COMPACTION TEST

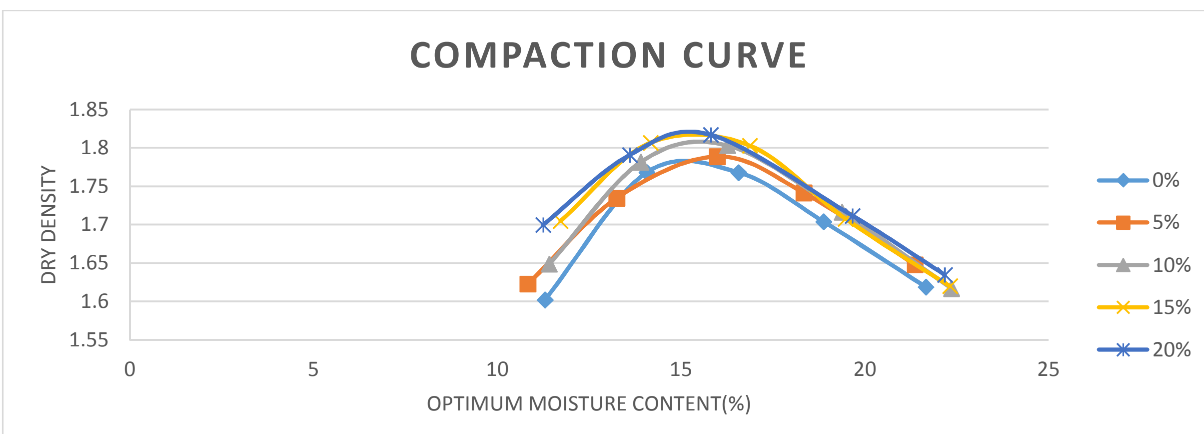

Figure 10: compaction curve

Maximum Dry density and optimum moisture content of different percentage (%) of blast furnace slag

5.3 UNCONFINED COMPRESSIVE STRENGTH

The strength of the ucs sample was determined in different %(0%, 5%, 10%, 15, 20%) in different curing period(0days, 3days, 7days, 15days).

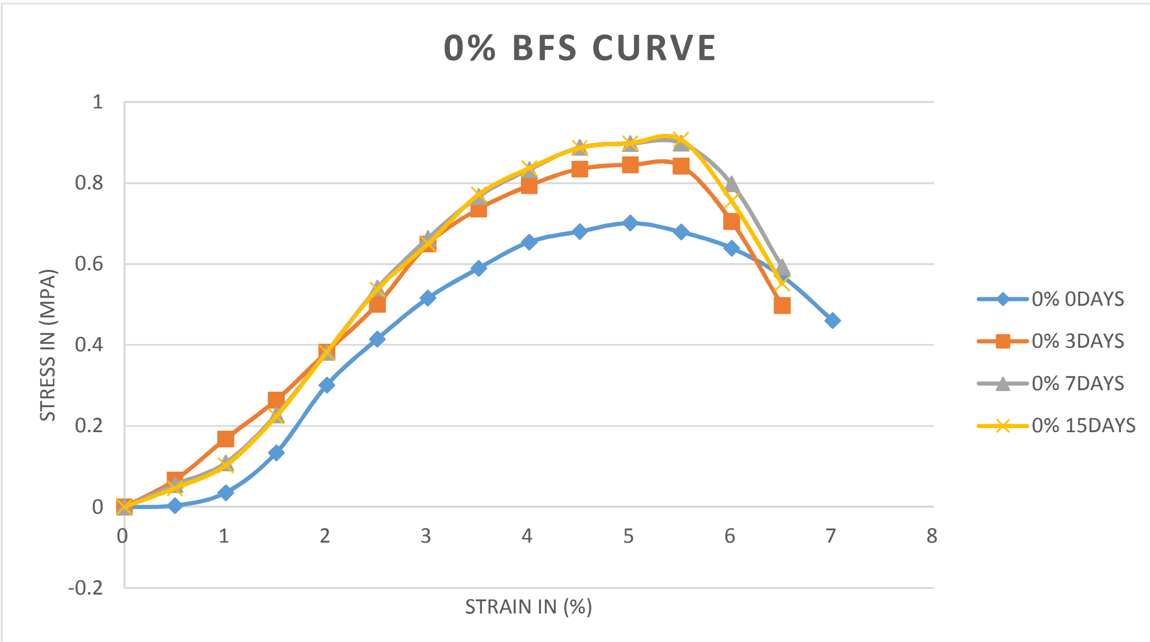

Figure 11:0% Blast furnace slag for different days

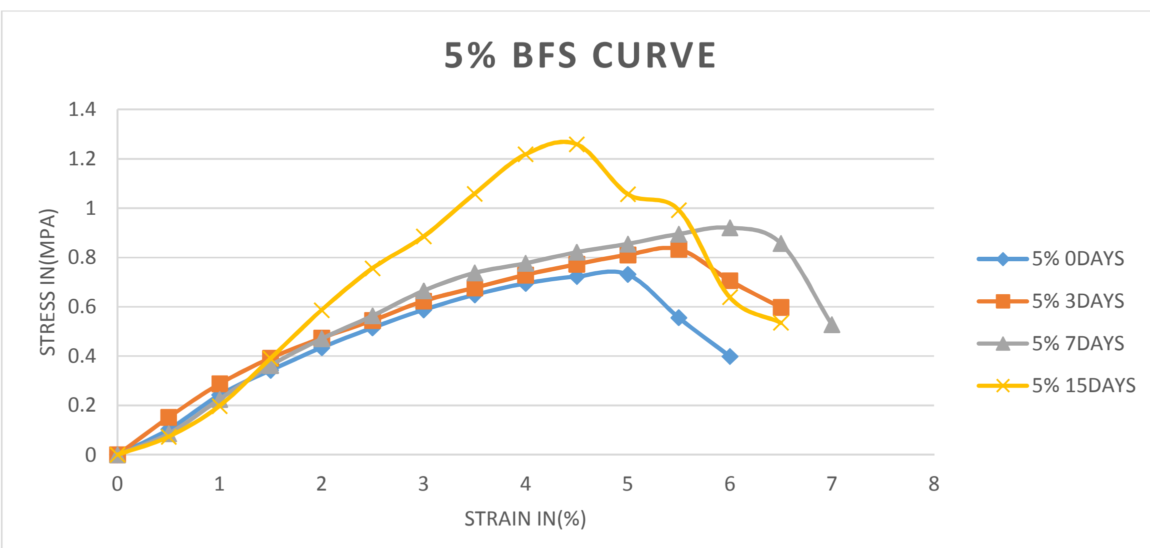

Figure 12: 5% Blast furnace slag for different days

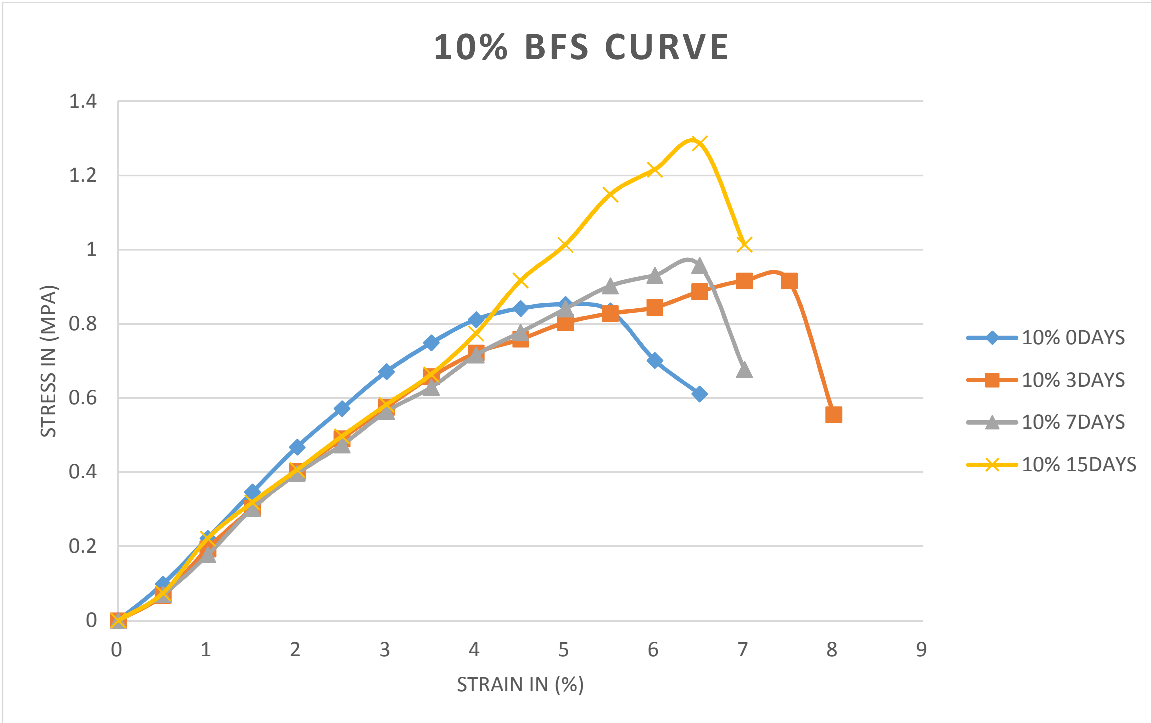

Figure 13: 10% Blast furnace slag for different days

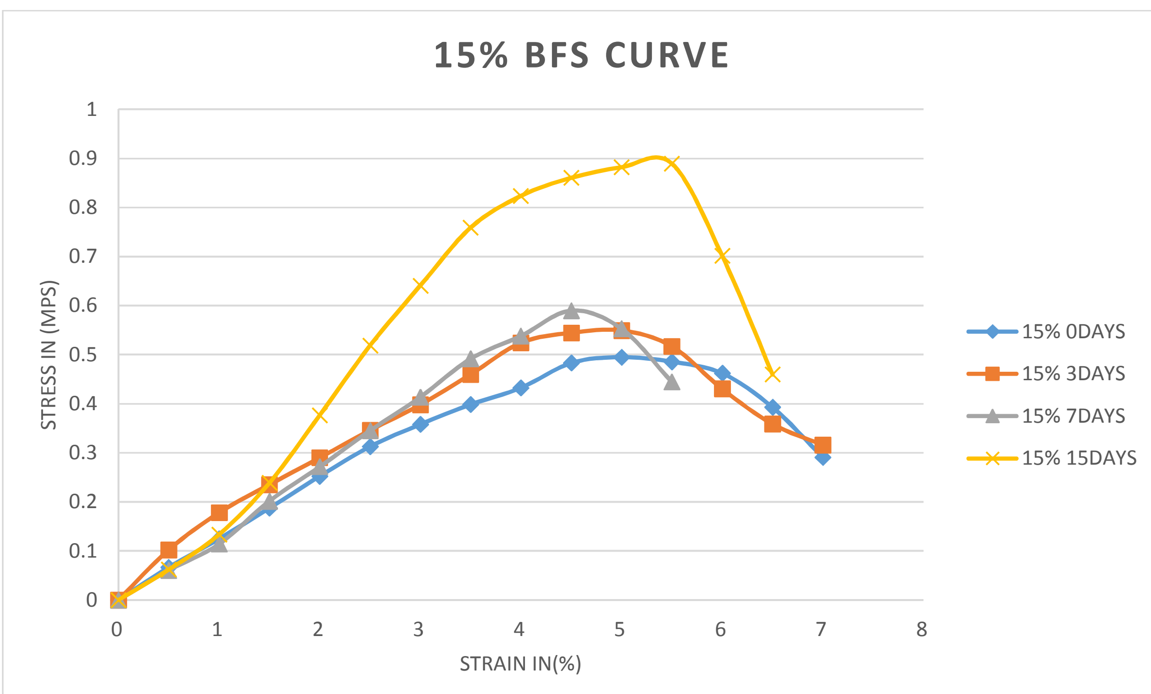

Figure 14: 15% Blast furnace slag for different days

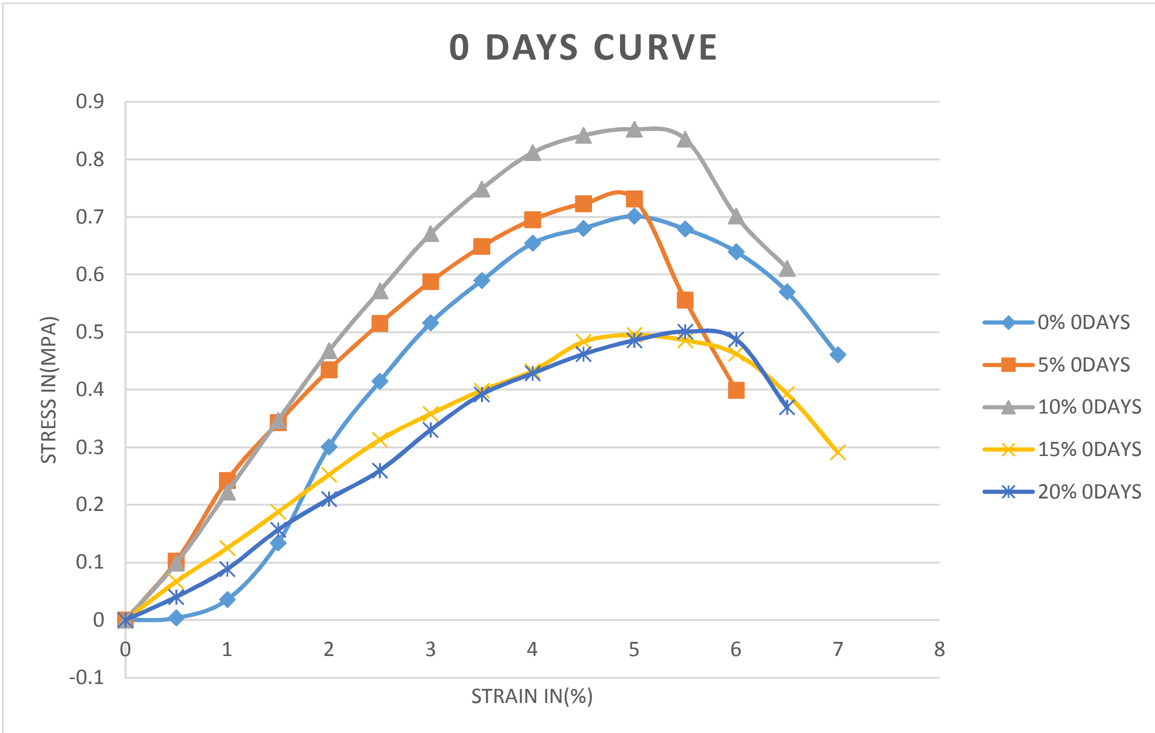

Figure 15: Blast furnace slag 0 days for different (%)

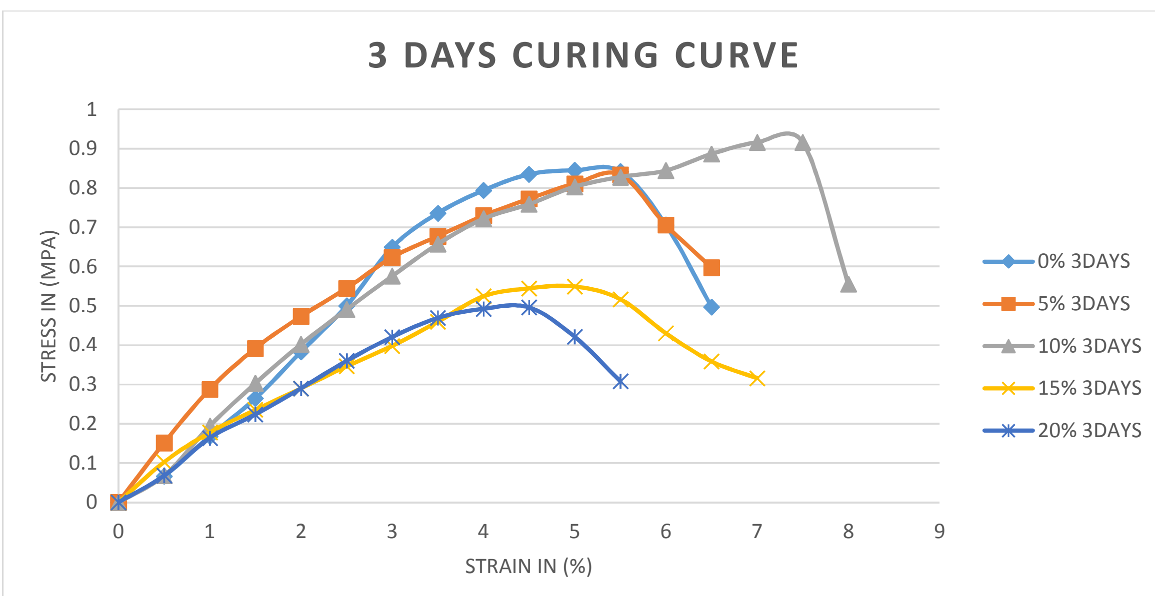

Figure 16: Blast furnace slag 3 days for different (%)

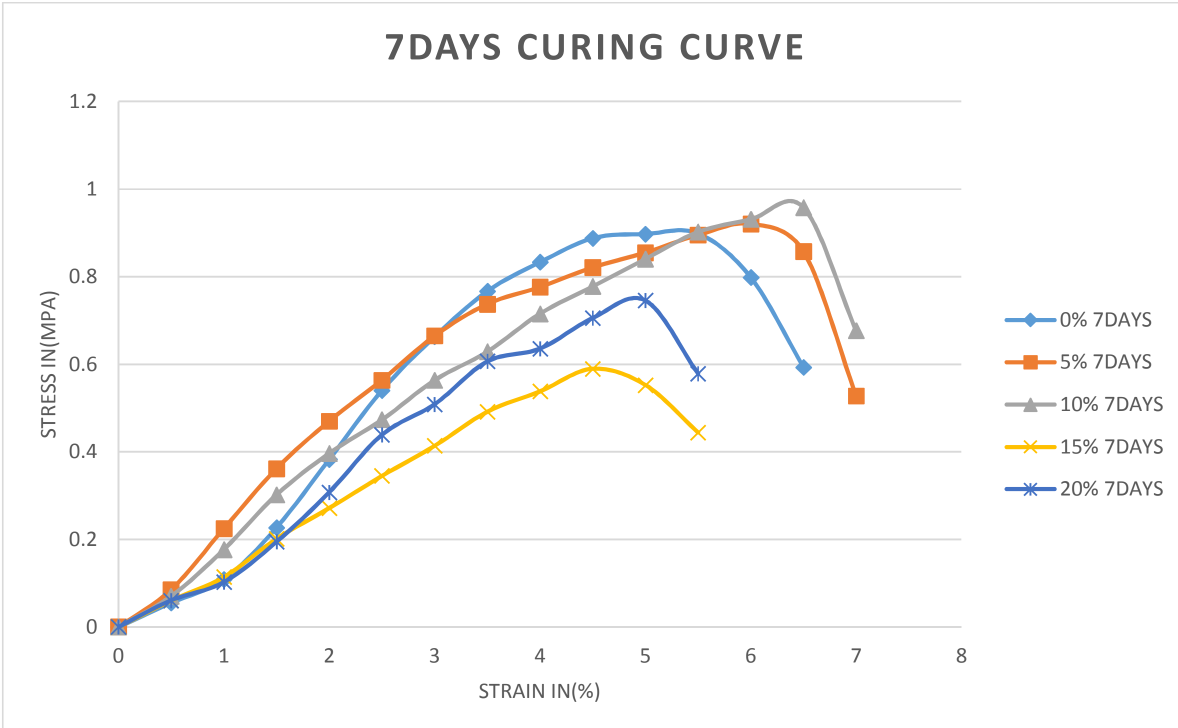

Figure 16: Blast furnace slag 7 days for different (%)

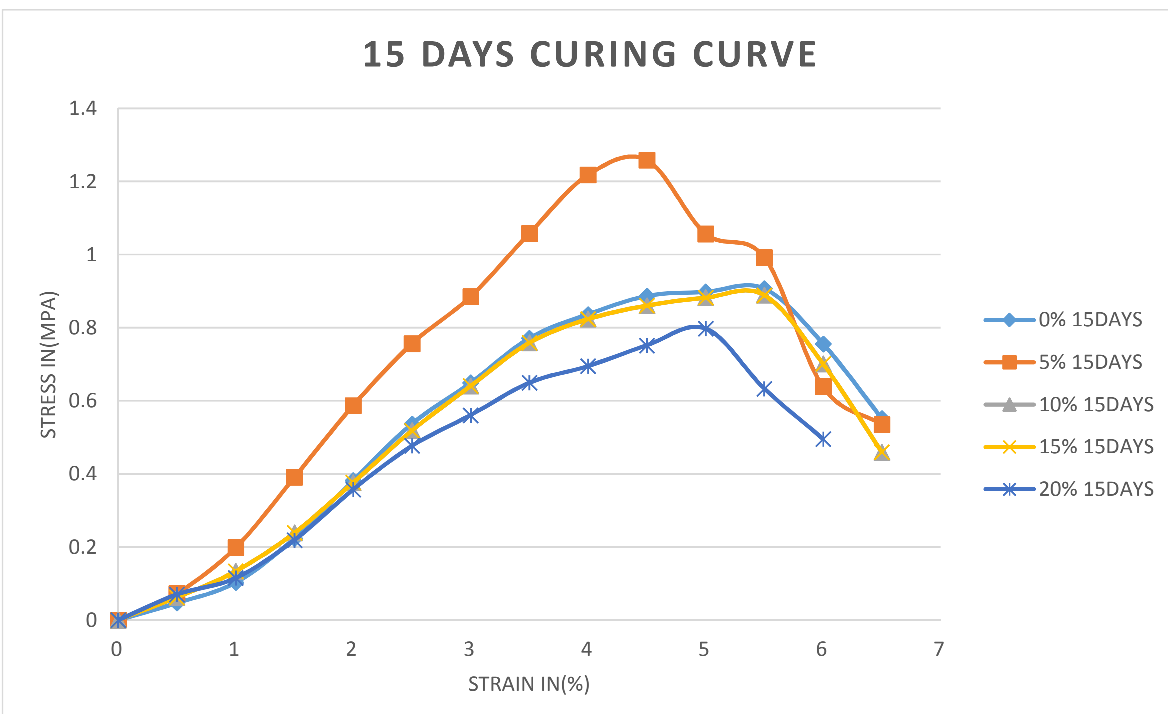

Figure 17: Blast furnace slag 15 days for different (%)

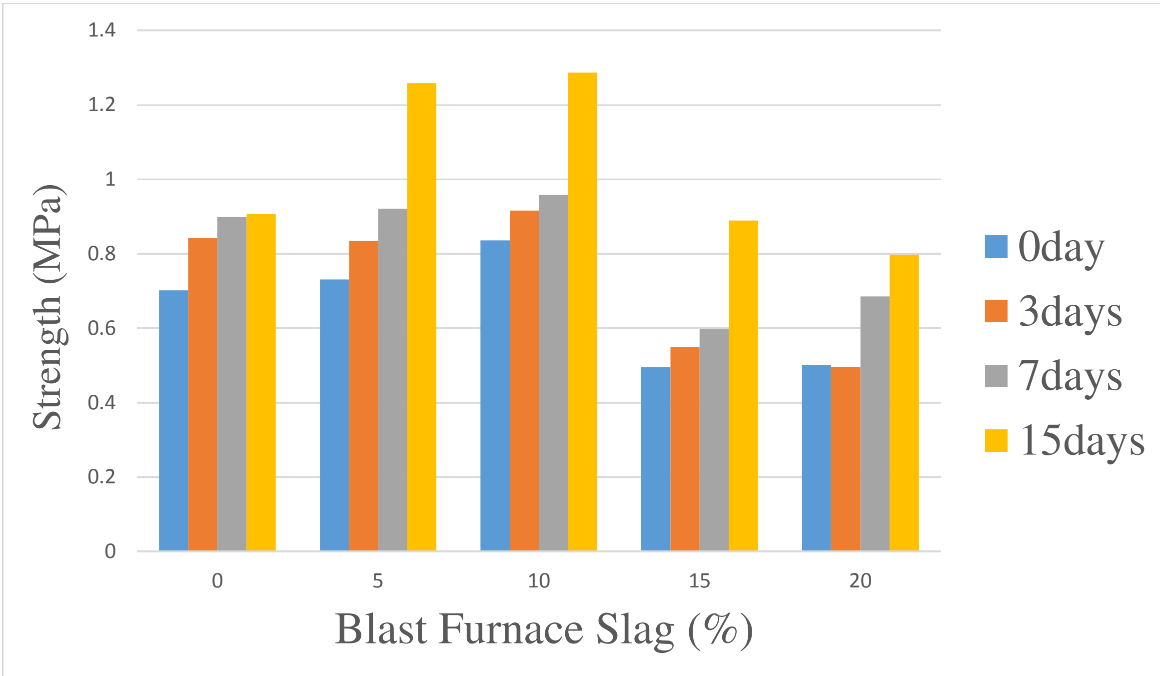

Figure 18: incremental strength for different (%) different days

Incremental Strength of 0 days,3 days,7 days,15 days addition of bfs

Days	**0%**	**5%**	**10%**	**15%**	**20%**
0 days	0.7013	0.731	0.8353	0.495	0.5008
3 days	0.842	0.834	0.916	0.549	0.496

7 days	0.899	0.921	0.958	0.599	0.685
15 days	0.907	1.259	1.287	0.899	0.798

CHAPTER 6

6.1 CONCLUSIONS

Based on the experimental results, the following conclusions were made:

- The Plasticity Index is decreasing up to a value of 27.6% with addition of 20% of blast furnace slag with red soil.
- The Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) are increasing by 2.3% and 33% respectively.
- The UCS value is maximum with addition of 10% of blast furnace slag afterwards the UCS value decreases with further addition in blast furnace slag.
- The UCS value increases with curing period.

REFERENCES

- Akinbinu, V. A. (2010). Preliminary Investigation into Utilization of Wastes from Iron and Steel Industries in Nigeria as Fine Aggregate Replacement in Concrete Application. Journal of Solid Waste Technology & Management.
- Balogun, L. A. (1991). Effect of Sand and Salt Additives on Some Geotechnical Properties of Lime-stabilised Black Cotton Soils. The Nig. Engr. 26 (4),
- BS 1377 (1990).Method of Testing Soil for Civil Engineering Purposes. BritishnStandard Institute (BSI), London.
- BS 1924 (1990). Method of Test for Stabilized Soils. British Standard institute (BSI),London.
- Charman, J. H. (1988). ‘Laterite in road pavements’, Special Publication 47: Construction Industry Research and Information Association, London.
- Emery, J. J. "Slag Utilization in Pavement Construction," *Extending Aggregate Resources.*ASTM Special Technical Publication 774, American Society for Testing and Materials,Washington, DC, 1982.
- Istrate, R. and Calimente, A. (2009). Slag – Utilisation in Road Construction – Experience and Solutions. Journal of Engineering Annals of Faculty of Engineering Hunedoara.
- Joulazadeh, M. H. and Joulazadeh, F. (2010). Slag: Value Added Steel Industry Byproduct. Archive of Metallurgy and Materials, Volume 55, Issue 4.
- Kalyoncu, R. S. (2001). Slag Iron and Steel. US Geological Survey Minerals Yearbook 2001.

  Kowalski, T. E. and Starry (Jr.), D. W. (2007). Modern Soil Stabilization Techniques. Paper prepared for presentation at the “Characterization and Improvement of Soils and Materials Session”, 2007 Annual Conference of the Transportation Association of Canada, Saskatchewan.
- Matawal, D. S. (1990). Compaction Characteristics of Some Tropical Laterite soils. OMC-CBR Relationship, Journal of Engineering Research, JER 2(2).
- Nippon Slag Association (2006). The Slag Sector in the Steel Industry. The JapanIron and Steel Federation, July 2006.
- Noureldin, A. S., and R. S. McDaniel. "Evaluation of Steel Slag Asphalt Surface Mixtures," Presented at Transportation Research Board 69th Annual Meeting, Washington, DC, January 1990.
- Osinubi, K. J. and Eberemu, A. O. (2006). Hydraulic Conductivity of Lateritic Soils Treated with Blast Furnace Slag. Electronic Journal of Geotechnical Engineering, EJGE, Vol. 11, Bundle D, pp. 1 -21.
- Hartlen, J., Carling, M & Nagasaka, Y. (1997) Recycling or reuse of waste materials geotechnical applications, *Proceedings of the second International Congress of Environmental Geotechnics*, Osaka, Japan, pp 1493-1513.
- JEGEL. *Steel Slag Aggregates Use in Hot Mix Asphalt Concrete*. Final Report, prepared by John Emery Geotechnical Engineering Limited for the Steelmaking Slag Technical Committee,april 1993.
- Mroueh, U. M., Laine-Ylijoki, J &Eskola, P. (2000), Life-Cycle impacts of the use of industrial by-products in road and earth construction, Waste Materials in Construction, WASCON 2000, *Proceedings of the International Conference on the Science and Engineering of Recycling for Environmental Protection*, Pergamon Press, Harrogate, England, Vol1.
- Takhelmayum1, savitha.A.L2, Krishna Gudi3 *1,2,3GSS Institute of Technology, VTU experimental studied on ground granulated blast furnace slag using fine and coarse*

*GGBS.***(ISSN 2250-2459,ISO9001:2008 certified journal) Volume 3, Issue 3, March 2013).**

- Utilization of lime, Slag and Flyash for improvement of colluvial soils in New South Wales, Australia, Geotechnical and Geological Engineering Journal, Vol 14, no. 3, PP 169-191.